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AUTHOR Olsen, Scott A.
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ABSTRACT

A study examined the relationship between Collegiate Assessment of Academic Proficiency (CAAP) critical thinking test scores and the extent to which students met core general education course requirements at Northeast Missouri State University (NMSU). Data used in the study were collected in required sophomore examinations as part of an established assessment program at NMSU, using a stratified random assignment design controlling three levels of entering ability as measured by American College Testing (ACT) composite scores. Critical Thinking was the independent variable and the CAAP Critical Thinking Test (CT) developed by ACT was the measure of critical thinking employed. Nine core requirement areas were selected: Communications, Mathematics, Sciences, Philosophy, Literature, Fine Arts, Foreign Languages, History and non-history Social Sciences. Patterns of critical thinking (CT) were investigated within each of these areas using a two-way unbalanced analysis of variance design and orthogonal polynomial contrasts. Significant trends in critical thinking scores were found for communications, science, and literature. In philosophy, a significant philosophy by ACT interaction effect was found. However, it should be noted that the relationships recognized were not necessarily cause and effect since certain content areas are more conducive to the development of critical thinking skills than others. Appended is NMSU's Liberal Arts and Science Core Curriculum. Includes 17 references. (LPT)

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Examining the Relationship Between College Core Course Areas and Sophomore Critical Thinking Test Scores

Scott A. Olsen

Northeast Missouri State University

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INTRODUCTION

In recent years there has been a call for increased attention in higher education to the development and evaluation of critical thinking skills (Association of American Colleges, 1985; National Institute of Education, 1984). Certainly the goal of improving the ability to think critically is one that is commonly stated by most colleges and universities, and there is evidence that critical thinking improves as students progress through college (Mentkowski & Stait, 1983; Bailey, 1979; Dressel & Mayhew, 1954). While one might expect increased critical thinking due to maturation alone, there is some evidence that after one year of college students do perform better on critical thinking measures than their matched high school peers who did not attend college (Pascarella, 1989). However when one looks at research examining the relationship between critical thinking and specific courses or patterns of courses found in college general education core requirements, there are mixed findings. A review and synthesis of college level critical thinking studies has been provided by McMillan (1987). McMillan's review cites several course area related studies, such as social sciences (Logan,1976; Jones, 1974; Dressel & Mayhew, 1954), debate (Jackson, 1961; Williams, 1951), specially designed psychology (Lyle, 1958), science and logic (Dressel & Mayhew, 1954), which show rather inconsistent findings and suggest that results will differ by institution.

Northeast Missouri State University (NMSU), like many universities, holds the enhancement of critical thinking skills as one of its important objectives which is presumed to be met largely within the university's liberal arts and sciences core. Within this context there are presently two issues at NMSU that motivate the current study: student advising and liberal arts and sciences curriculum review.

NMSU is currently looking at ways to improve its advising of students. With regard to critical thinking objectives, better advising implies identification of those students who are likely to have weak critical thinking skills, and the identification of course areas that have the highest probability of aiding in the development of critical thinking skills. A separate assessment study at NMSU has, through the regression of critical thinking scores on entering freshmen characteristics, provided a way of identifying those students who are most likely to have difficulty with critical thinking objectives. The present investigation attempts to identify those course areas that have a significant relationship to critical thinking performance. Thus this study attempts to complete the information needs for better advising in relationship to critical thinking objectives.

NMSU is also in the process of reviewing its liberal arts and sciences core with an eye toward the possible restructuring of that core. In light of liberal arts and sciences general education goals for the enhancement of

critical thinking skills, it is important to identify those core areas (if any) that have significant relationships to critical thinking skills, so that informed judgements may be made in the review process and any possible restructuring proposals.

The primary objective of this study is to examine the relationship between the degree to which students have met liberal arts and sciences core requirements at Northeast Missouri State University and sophomore critical thinking skills. The nine core requirement areas investigated are: Communications, Mathematics, Sciences, Philosophy, Literature, Fine Arts, Foreign Languages, History and non-history Social Sciences (see Appendix A for specific courses in these areas). Critical Thinking is defined by the Collegiate Assessment of Academic Proficiency (CAAP) test of Critical Thinking (CT), a relatively new test aimed at college sophomore level students, and a test that to the author's knowledge has not been used in a study of this type. Since entering ability is highly correlated with critical thinking skills, this study will control for three levels of ACT composite scores. Therefore the basic question to be addressed is: When controlling for entering ACT composite scores, and within each core area (e.g. Communications, Sciences, etc.), is the pattern of mean CT scores such that higher critical thinking skills are associated with higher levels of meeting the core area requirements?

METHODOLOGY

Data Source

All data for this study were obtained at Northeast Missouri State University (NMSU) from students taking their required sophomore examinations during the fall of 1988 and the spring of 1989. NMSU is a selective medium sized public liberal arts and sciences state university. The university's total enrollment is around 7000 undergraduate and graduate students. The freshmen class typical consists of between 1600 and 1700 traditional students selected from an applicant pool of approximately 7500. The mean American College Testing (ACT) assessment battery composite score ranges between 23 and 24.5 (1987-88 scale) for entering freshmen.

The university has a long history of outcome assessments starting in 1974. As one part of the assessment program, NMSU requires that all students take specified tests measuring general educational development near the end of their sophomore year, defined as between 44 and 76 semester hours of credit. Students must sit for sophomore examinations before they can enroll for course work beyond 76 hours.

During the fall of 1988 and spring of 1989 there were 927 sophomores who were administered the Collegiate Assessment of Academic Proficiency (CAAP) Critical Thinking (CT) test along with other tests used by NMSU. This is approximately 75% of all NMSU sophomores, with the remaining 25% administered a set of examinations which excluded this CT test. Approximately 60% of those taking the CT test also took the College Outcomes Measures Program (COMP) objective test during the same testing session. The remaining 40% took CT along with three other modules of the CAAP (Writing, Reading, and Mathematics) during their testing sessions. For those who were administered the CT and COMP combination, half took the COMP test immediately before the CT test,

while the other half took the CT test immediately before the COMP test, thereby counterbalancing test order. Similarly for those who were administered CT with three other CAAP tests, 25% took CT first, 25% second, 25% third and 25% took CT last to again counterbalance possible test order effects. All testing sessions were between three and one-half and four hours in length.

Within each semester the assignment to testing session and to testing order was done using a nine cell stratified random design controlling for three levels of entering ACT composite scores (approximate high, middle and low thirds of the distribution) in combination with three levels of total credit hours earned (approximate high, middle and low thirds of the distribution). Thus the data in this study were collected in required sophomore examinations as part of an established assessment program at NMSU, using a stratified random assignment design controlling for college entry level of ability and total college credit hours at time of testing, and with test order counterbalanced.

Measurement of Critical Thinking

Critical thinking is the dependent variable in this study, and the Collegiate Assessment of Academic Proficiency (CAAP) Critical Thinking test (CT) developed by American College Testing (ACT) programs is the measure of critical thinking employed. CT is a recently constructed test specifically designed for college level students. The Report on the Technical Characteristics of CAAP: Pilot Year 1 1988-89, describes CT as a 40 minute test comprised of 32 items measuring "the ability to clarify, analyze, evaluate and extend arguments" where argument is defined as "a sequence of statements which includes a claim that one of the statements, the conclusion,

follows from the other statements" (ACT, 1989). It further states that

> "The test consists of four passages that are representative of the kinds of issues commonly encountered in a postsecondary curriculum. A passage typically presents a series of subarguments in support of a more general conclusion or conclusions. Each passage presents one or more arguments and uses a variety of formats, including case studies, debates, dialogues, overlapping positions, statistical arguments, experimental results, or editorials. Each passage is accompanied by a set of multiple-choice test items." (p. 13)

The report goes on to describe the content of the CT as analysis of the elements of arguments (62%), evaluation of arguments (19%) and extension of arguments (19%). The CT is reported to have a reliability of between .81-.82 (KR-20), a standard error of measurement of 2.3 for scaled scores that have a maximum range of 45 to 75.

Classifications Within Core Requirement Academic Areas

In this study the independent variable is the extent to which sophomores had completed their general education core requirements within each of nine broad academic areas at NMSU--Appendix A lists these requirements as found in the university bulletin. The nine areas of investigation are Communications, Mathematics, Science, Philosophy, Literature, Fine Arts, Languages, History and Social Sciences (other than history). Within each of these nine areas this study examines the relationship between the degree to which the core requirement has been met and critical thinking skills.

In order to define the independent variable for each of the nine areas, the course records were examined for each of the 925 students who had the CT test as part of their sophomore examination battery. Only courses taken at NMSU were included in this review of records. Based upon the core courses they had completed within an area at the time of their sophomore examination, students were classified according to the degree to which they had met that

area's core requirements. Where courses in an area were hierarchical in nature having prerequisite competencies, such as in mathematics where for example the course Essentials of Calculus necessitates prerequisite mathematics competencies at level of the course Elementary Functions, students were classified by the hierarchical level at which they met the requirement. Where courses in an area were survey type courses without area prerequisite competencies required, such as in the literature area, students were classified by the number of courses in the requirements listing that could be used to satisfy that area's general education requirement. Within each of the nine areas under study all student classifications were mutually exclusive.

The number of classifications in each area was determined by the number of possible identifiable and meaningful distinctions between levels of meeting a requirement and the number of students for each cell classification. In some cases otherwise identifiable classifications had to be collapsed to provide a sufficient number of students in cells for meaningful analysis. For all nine areas there were at least three levels defined in this way with the maximum number of levels being seven for mathematics. Specific definitions for each of the nine areas along with descriptive statistics for each of the classifications will be given near the beginning of each area-based subsection of the results. Some students were deleted in situations where students had relatively rare patterns of course work in an area that defied classification into a group of reasonable size.

Controlling for Entering Ability Using ACT

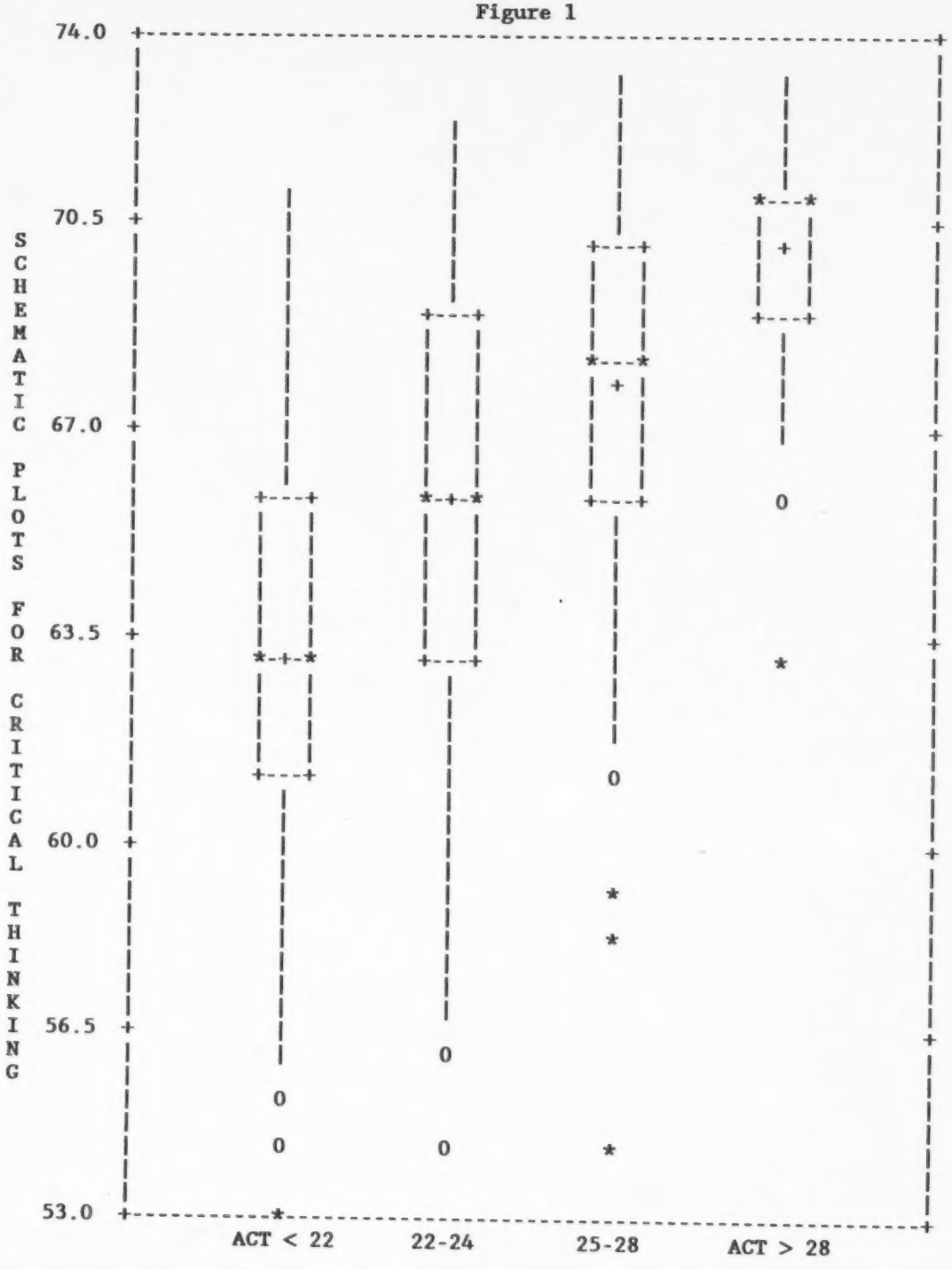
Generally one would expect CT scores to be correlated with student entering ability. Thus to determine the relationship between levels of meeting requirements within each academic area and critical thinking, it was

necessary to control for entering ability. Since nearly all students enter NMSU with ACT assessment battery scores, ACT composite scores were used as the basis for this type of control.

To control for entering ability three levels of ACT were defined, each having about one third of the students. The three ACT levels were defined by score ranges of 7-21, 22-24, and 25-28. For the lowest level, there simply were no ACT composite scores lower than 7, and in fact the single score of 7 was somewhat of an outlier. For the highest level there were scores above 28, however students with such scores were deleted because of a CAAP-CT ceiling effect found at NMSU for students with ACT composite scores of 29 and above. For the 811 students remaining in the study, the correlation between sophomore CT scores and freshmen ACT composite scores was 0.538.

Figure 1, shows the CT score schematic distributional box plots for the three levels of ACT used in this study as well as for students with ACT scores greater than 28 who were deleted from this study. For those unfamiliar with such plots, the upper line forming the box is at the 75th percentile of the distribution, the lower line forming the box is at the 25th percentile of the distribution, the middle line, "*---*", is the median, the lines extending from the box on either end cover the approximate 95% trimmed range of the distribution, and the plus sign, "+", locates the mean. Clearly the interquartile range, as well as any other measure of variation in CT scores, is greatly reduced for the high ACT group. Indeed the range is so restricted at the top of the high ACT group's CT score distribution that the 50th percentile (median) and the 75th percentile cannot be distinguished at the level of precision that the plot offers with the CT median at approximately 71. In short, the evidence of CT ceiling effect seems compelling for the

Figure 1


74.0
70.5
67.0
63.5
60.0
56.5
53.0
SCHEMATIC PLOTS FOR CRITICAL THINKING
ACT < 22
22-24
25-28
ACT > 28

group with ACT scores above 28. Therefore, since the inclusion of scores of such suspect validity could seriously contaminate the effects under study and inhibit the ability to make meaningful conclusions, those with an ACT composite score greater than 28 were deleted from this study.

Analysis

For each of the nine areas, the levels at which students met area core requirements were crossed with the three levels of ACT in an unbalanced analysis of variance design. All statistics for this unbalanced design were obtained using the Statistical Analysis System (SAS), specifically, the general linear models procedure with Type III sums of squares and least squares means (SAS, 1985). Because of the unbalanced nature of the two-way design controlling for three levels of ACT, all tests of means were based upon least squares means resulting from the design. These least squares means were reported along with the usual analysis of variance summary tables for each of the nine core requirements areas.

The primary focus of this study was on the relationship between critical thinking skills and the extent to which students have met general education core requirements at NMSU. The presumption was that specific patterns of CT scores would emerge as one moved from lower levels of meeting the requirements in an area to higher levels of meeting those requirements. To test for specific independent patterns in least squares mean CT scores across area classifications, a trend analysis based upon pre-planned orthogonal polynomial contrasts was used. Such an analysis uses the degrees of freedom associated with the area classifications to test separate hypotheses about specific trends in the CT least squares means, rather than to test the usual global hypothesis that all classification least squares means are equal. In all nine

areas, hypotheses of both linear and quadratic trend were tested. Where the number of degrees of freedom allowed, hypotheses of cubic and quartic trends were also tested.

In performing trend analysis the area classification levels were given a quantitative relationship to one another. All trend analyses in this study treat the levels of the area classification variable as equal interval. In other words, the level number associated with each set of area classifications may be thought of as the quantitative scale underlying the trends hypothesized for purposes of this investigation. The ordinal property of these area classification scales is easily defended, however, it should be recognized that the interval property is simply the assumption that seemed most generally applicable, most neutral, most easily understood by faculty and least complicated with the smallest chance of skewing the results.

To aid in the interpretation of findings related to area classifications, all pair-wise comparisons between area classification least squares means were done. The p-values for the T-statistic comparing pairs of least squares means are reported in the least squares means tables.

The second important question addressed in this research pertains to the uniformity of differences in cell least squares means at the three different levels of ACT. In other words for students in a lower entering ability group (i.e. ACT<22), was the relationship between CT and level of meeting the area general education requirement the same as it was for those students in the higher levels of entering ability (ACT=22-24 & ACT=25-28). This area by ACT interaction hypothesis was tested using the F-statistic from the standard analysis of variance summary table which was reported for each of the nine academic areas. Notice that this interaction F-statistic is the only one of interest in the standard analysis of variance summary tables for two reasons:

(1) the F-statistic for the area classifications (though reported) is replaced by the F-statistics related to the orthogonal polynomial contrasts in the trend analysis (one should not use the same degrees of freedom twice), and (2) ACT is expected to be significant since it is known to be related to CT and is included in the design to control for entering ability. If a significant interaction emerges, pair-wise comparisons of relevant cell least squares means within levels of ACT will be used to identify the nature of the interaction.

All of the above hypotheses were tested using alpha=0.10 as the criterion for significance. This criterion was believed to be more appropriate for this initial exploratory study than more stringent criterion often employed. Indeed, the consequences of falsely rejecting a null hypothesis (Type I error) in this study are that NMSU may follow up on a lead regarding its curriculum, advising, etc., that may not result in anything better than what currently exists, whereas, the consequences of not rejecting a null hypothesis when it should be rejected (Type II error) are that NMSU would fail to recognize and follow up on a potentially beneficial lead. Thus alpha=0.10 seemed the most reasonable choice of criterion.

The only exception to using alpha=0.10 was in routine checks of the homogeneity of variances assumption done prior to each analysis of variance. Hartley's F-max statistic was used for this purpose. However, with unequal sample sizes, as was the case in this study, the approximation to the F-max using the mean sample size may be liberal. Therefore, F-max statistics were judged using alpha=0.05. The results of the F-max test are reported along with area classification definitions and cell descriptive statistics near the beginning of each area subsection of the results.

RESULTS

The results for each of the nine academic areas of general education requirements are reported in separate subsections and in a parallel format. The classifications of the degree to which core requirements in that area have been met are defined at the beginning of each subsection. These area classifications are then used in the two-way unbalanced analysis of variance design to test for trend and interaction effects controlling for three levels of entering ability as measured by ACT.

Communications

For the communications general education requirements area, four classifications of students based upon the extent to which they met the requirements were possible. These communications area classifications are defined in Table 1. Table 1 also reports descriptive statistics for each ACT level of each classification. Two of the 811 students with critical thinking scores did not fit into one of the four communications classification levels, and they were deleted from this analysis.

The results for the communications area are summarized in Table 2. The upper portion of the table gives the orthogonal polynomial contrast results for the trend analysis as well as the standard analysis of variance summary statistics. The linear trend was significant (alpha=0.10). There was no ACT by Communications level interaction. And of course the three levels of control imposed using ACT were highly significant as expected by design.

Table 1
Communications Area Classification Definitions
Cell Sizes, Critical Thinking Means and Standard Deviations

COMMUNICATIONS LEVEL - ABBREV.	DEFINITION	ACT LEVEL	N	CT MEAN	CT STD
1 - NONE	No required communications courses completed at NMSU.	ACT<22	14	65.50	3.13
		22-24	18	66.28	3.04
		25-28	20	67.85	3.53
2 - COMP. I	English Composition I is the only communications course completed at NMSU.	ACT<22	67	63.13	3.79
		22-24	80	66.04	3.17
		25-28	110	67.60	2.87
3 - SPEECH	Speech Communications is the only communications course completed at NMSU.	ACT<22	15	63.53	2.80
		22-24	23	66.00	3.22
		25-28	37	68.27	2.68
4 - BOTH	Both English Composition I and Speech Communications courses have been completed at NMSU.	ACT<22	131	63.11	3.53
		22-24	148	65.57	3.39
		25-28	146	67.79	2.73
F-max = 1.998	Not significant at the 0.05 level for 12 variances with Mean(n)=67.				

To determine the direction of the significant linear trend, the critical thinking (CT) least squares means for the four levels at which the communications requirements were met must be examined. The lower portion of Table 2 reports these least squares means for this unbalanced design, along with the T-statistic probabilities associated with each of the six possible pair-wise comparisons for these four means. Clearly the linear trend has a negative slope. That is, critical thinking scores go down as one moves from the "NONE completed" group (CT=66.54) to the "BOTH English Composition I and Speech Communications completed" group (CT=65.49), contrary to the upward trend that most would hypothesize. Furthermore Table 2 shows significantly

Table 2
Communications Area
Analysis of Critical Thinking Scores
By Level of General Education Communications Requirements Met

SOURCE	DF	TYPE III SS	F VALUE	PR > F
Contrasts:				
Linear Trend	1	36.42911444	3.56	0.0595
Quadratic Trend	1	6.22212941	0.61	0.4357
Cubic Trend	1	22.20681938	2.17	0.1411
Communications	3	57.15826258	1.86	0.1345
ACT	2	1054.74270279	51.54	0.0001
Communications*ACT	6	55.34393088	0.90	0.4931
Error	797	8154.87434396		

LEAST SQUARES MEANS

COMM LEVEL	CT LSMEAN	STD ERROR LSMEAN	PROB > |T| HO: I/J	LSMEAN(I) = LSMEAN(J) 1	2	3	4
1 NONE	66.543	.449	1		.054	.309	.027
2 COMP I	65.591	.204	2	.054		.439	.694
3 SPEECH	65.935	.395	3	.309	.439		.295
4 BOTH	65.490	.155	4	.027	.694	.295	

better (comparison-wise alpha=.10) sophomore critical thinking performance for those who have not completed a communications area required course than for either those who have completed English Composition I (p=0.054) or for those who have complete both English Composition I and Speech (p=0.027).

For the communications area these results are rather misleading and must be interpreted differently than similar results in other general education areas of this study. This is due to a selection bias that exists for NONE classification of NMSU students. This bias results from the fact that students were classified for purposes of this study based only upon the courses completed at NMSU. However, there are a large number of NMSU students

who enter with College English Composition I credit earned in college level courses taken in some of the larger high schools. Based upon fiscal year 1990 figures about 14.6% of NMSU's entering freshmen came with such credit for English Composition I. These percentages are far greater than for any other NMSU core requirements area, with mathematics being the second highest with only 4.5% entering with high school based college credit. Assuming that this percentage was approximately the same for the 1988-89 sophomores in this study (for whom such percentages were not readily accessible) approximately 118 (14.6% of 809) students may have already had an equivalent to English Composition I without this being reflected in the classification procedures used. The NONE (at NMSU) group had 52 students in it while the SPEECH (at NMSU) had 75 students in it for a total of 127 students of which 118 probably already had English Composition I in a high school based advanced program. Moreover since one must be an advanced student to qualify for college course work while still in high school, and since these were the students who were probably the majority of the NONE communications area classification in this study, it is not so surprising that this NONE classification had higher critical thinking scores than were found in the other three classifications.

Since more advanced high school students would tend to have higher ACT scores, a quick descriptive check was done by looking at what happened when students with ACT composite scores above 28 were deleted from this study due to the probability of a CT ceiling effect. The number of students in NONE category dropped by 27.8% and those in the SPEECH category dropped by 15.7%, whereas, those in the COMP I group dropped by 13.5% and those in the BOTH group dropped by only 8.6%. This would seem to support the selection bias reasoning presented.

Further notice that this explanation was clearly consistent with the pattern of p-values for the pair-wise comparisons of least squares means in Table 2. In short it was likely that the significant trends observed were more an indication of the relationship between pre-college advanced course work and later critical thinking skills than between NMSU communications course work and critical thinking.

If one excludes the contaminated NONE and SPEECH classifications from consideration, one is left only with the comparison between those who took Composition I at NMSU and those who took both Composition I and Speech at NMSU. From the lower portion of Table 2 it is seen that for this remaining comparison there is no significant difference ($p=0.694$) in critical thinking scores.

In summary, while significant trends were identified for the levels of course work in communications defined in this study, this definition process did not control for advanced external course work which was more prevalent for more advanced students. Thus without additional controls for this confounding selection related variable the significant trend effects found for the communications area must be viewed with great suspicion. The only comparison between uncontaminated levels of communications course work groupings leads to a conclusion of no relationship between communications course work and critical thinking skills. This seems to be the best general conclusion for the communications area.

Mathematics

The mathematics area gave rise to seven hierarchical levels of meeting the general education mathematics requirements. Table 3 defines these

Table 3
Mathematics Area Classification Definitions
Cell Sizes, Critical Thinking Means and Standard Deviations

MATHEMATICS LEVEL - ABBREV.	DEFINITION	ACT LEVEL	N	CT MEAN	CT STD
1 - NONE	No mathematics courses completed at NMSU.	ACT<22	36	62.86	4.11
		22-24	31	66.55	3.48
		25-28	24	67.38	3.62
2 - ALGEBRA ONLY	College Algebra is the only course completed at NMSU.	ACT<22	66	63.06	3.91
		22-24	51	65.55	2.96
		25-28	33	67.73	2.86
3 - ALG. & TRIG.	Both College Algebra and Plane Trigonometry have been completed. This substitutes for Elem. Func.	ACT<22	39	63.77	3.21
		22-24	49	65.84	3.68
		25-28	34	67.79	2.67
4 - ELEM. FUNC.	Elementary Functions has been completed at NMSU. This is the minimum mathematics requirement.	ACT<22	24	63.46	3.69
		22-24	31	65.32	2.91
		25-28	44	67.84	2.96
5 - STAT or EC + <	Statistics or Essentials of Calculas plus lower level math. all completed at NMSU.	ACT<22	28	63.50	3.02
		22-24	34	65.59	3.90
		25-28	45	67.76	2.85
6 - STAT + EC OR >	Statistics and Essentials of Calc. or one higher level mathematics course completed at NMSU.	ACT<22	30	63.37	3.26
		22-24	53	66.21	2.73
		25-28	81	67.83	2.56
7 - HIGHER >= TWO	Two or more higher level mathematics courses completed at NMSU.	ACT<22	6	62.17	3.32
		22-24	20	65.15	3.63
		25-28	52	67.90	2.89
F-max = 3.143	Not significant at the 0.05 level for more than 12 variances with Mean(n)=39.				

seven mathematics area classifications. The level number shown represents the scale used for trend analysis. Notice that the difficulty in finding students with ACT scores below 22 who met their mathematics requirement in the most rigorous fashion probably resulted in the cell size of n=6. This was the only

academic area in which a cell size fell below the target minimum size of n=12. However, this area was the best place for a small cell since it was also the area with the greatest number of classifications.

The trend and analysis of variance results for the mathematics area are summarized in Table 4. There were no significant effects except, of course, for the controlling variable, entering ACT composite score.

Table 4
Mathematics Area
Analysis of Critical Thinking Scores
By Level of General Education Mathematics Requirements Met

SOURCE	DF	TYPE III SS	F VALUE	PR > F
Contrasts:				
Linear Trend	1	2.61584326	0.25	0.6159
Quadratic Trend	1	7.38116981	0.71	0.3994
Cubic Trend	1	6.81548977	0.66	0.4181
Quartic Trend	1	2.92893162	0.28	0.5955
Mathematics	6	24.55158346	0.39	0.8831
ACT	2	1990.54739815	95.85	0.0001
Math*ACT	12	63.19608403	0.51	0.9109
Error	790	8203.04598876		

LEAST SQUARES MEANS

MATH LEVEL	CT LSMEAN	STD ERROR LSMEAN	PROB > |T| HO: LSMEAN(I) = LSMEAN(J) I/J	1	2	3	4	5	6	7
1 NONE	65.595	.343	1		.734	.650	.910	.966	.639	.404
2 ALGEBRA ONLY	65.446	.274	2	.734		.379	.826	.687	.359	.528
3 ALG. & TRIG	65.800	.295	3	.650	.379		.561	.669	.999	.226
4 ELEM. FUNC.	65.541	.334	4	.910	.826	.561		.873	.547	.451
5 STAT or EC + <	65.615	.317	5	.966	.687	.669	.873		.657	.376
6 STAT + EC or >	65.800	.273	6	.639	.359	.999	.547	.657		.217
7 HIGHER >= TWO	65.074	.522	7	.404	.528	.226	.451	.376	.217	

Science

Critical thinking (CT) scores were compared across four classifications of the degree to which general education science requirements at NMSU were met. Specific definitions for these four classifications appear in Table 5. The cell sizes, mean CT scores and CT score standard deviations are given to the right of each definition for each of the three levels of ACT. When

Table 5
Science Area Classification Definitions
Cell Sizes, Critical Thinking Means and Standard Deviations

SCIENCE LEVEL - ABBREV.	DEFINITION	ACT LEVEL	N	CT MEAN	CT STD
1 - NONE OR 1-100	Either none or one 100-level core science course completed at NMSU--requirement not met.	ACT<22	82	62.65	3.79
		22-24	67	65.42	3.16
		25-28	86	67.36	2.87
2 - TWO & NOT MET	Two core science courses completed at NMSU but requirement not met.	ACT<22	23	62.74	2.99
		22-24	39	65.97	3.38
		25-28	53	68.34	3.12
3 - TWO & REQ MET	Two 100-level core science courses completed at NMSU meeting minimum requirement.	ACT<22	92	63.97	3.38
		22-24	124	65.84	3.39
		25-28	120	67.81	2.50
4 - REQ. MET	Two or more higher level core science courses completed to meet the NMSU requirement.	ACT<22	32	63.19	3.68
		22-24	39	66.13	3.10
		25-28	54	67.85	3.09

F-max = 2.294 Not significant at the 0.05 level for 12 variances with Mean(n)=68.

constructing these definitions the distinction between students in the second and third levels was a difficult one to make. The two courses in the second level are usually the result of a more rigorous sequence within a specific science discipline (e.g. Physics) even though fewer hours of credit might be

awarded in certain sequences (e.g. Chemistry). On the other hand those who have met the requirement with two science courses (level 3) have experience in two disciplines and will always have at least 8 hours of credit. These considerations along with the fact that level 3 does meet the stated NMSU requirement whereas level 2 does not, lead to the definitions used.

The results of the analysis of critical thinking scores for the science requirement classifications controlling for ACT are summarized in Table 6.

Table 6
Sciences Area
Analysis of Critical Thinking Scores
By Level of General Education Sciences Requirements Met

SOURCE	DF	TYPE III SS	F VALUE	PR > F
Contrasts:				
Linear Trend	1	29.33663404	2.88	0.0903
Quadratic Trend	1	18.77297013	1.84	0.1753
Cubic Trend	1	0.00301016	0.00	0.9863
Science	3	75.60601008	2.47	0.0607
ACT	2	2292.89564525	112.36	0.0001
Science*ACT	6	53.72133531	0.88	0.5108
Error	799	8152.48074864		

LEAST SQUARES MEANS

SCIENCE LEVEL	CT LSMEAN	STD ERROR LSMEAN	PROB > |T| HO: I/J	LSMEAN(I) - LSMEAN(J) 1	2	3	4
1 NONE OR 1-100	65.142	.210	1		.153	.008	.107
2 TWO & NOT MET	65.684	.316	2	.153		.605	.929
3 TWO & REQ MET	65.871	.176	3	.008	.605		.663
4 REQ MET	65.723	.292	4	.107	.929	.663	

There was one significant effect other than the expected effect for the controlling levels of ACT. This significant effect was for the linear trend contrast. The lower portion of Table 6 displays the CT least squares means

for the science classifications in the unbalanced design. As can be seen from these means the linear trend was such that on the average the higher critical thinking scores were related to higher levels of meeting the NMSU core science requirements.

Notice from Table 6 that although a significant linear trend existed, the least squares mean for the highest science level (level 4) was lower than that of the next to the highest science level (level 3). This was due to the fact that level 3 had the greatest number of students, whereas level 4 had the fewest, which implies the relative influence each exerted on the linear trend.

Finally one will recognize from Table 6 that the only significant pair-wise comparison ($p=0.008$) implies that the mean critical thinking score for students with the NMSU minimum science requirement completed (65.87) was higher than that of those who had at most one 100-level science course completed (65.14). In fact, this was a significant difference at the experimental-wise alpha criterion of 0.167 (0.10/6) for the family of 6 comparisons.

In conclusion, the higher levels of critical thinking existed for NMSU students who met their science core requirements in more complete or rigorous fashion when controlling for entering ability as measured by ACT. Among the four levels of meeting the science requirements the difference between critical thinking scores for those who had completed at most one science course and those who had met the minimum science requirement with two 100-level courses, was significant in favor of those who had met the requirement.

Philosophy

Critical thinking scores were compared across three classifications of the degree to which general education philosophy courses were completed. It should be noted (see appendix A) that a student can meet humanities requirements at NMSU without philosophy, hence the numbers of those taking philosophy courses were fewer than in many other areas of the NMSU core. The philosophy level classifications were defined as seen in Table 7 with cell sizes along critical thinking means and standard deviations given for each ACT level of the classification.

Table 7
Philosophy Area Classification Definitions
Cell Sizes, Critical Thinking Means and Standard Deviations

PHILOSOPHY LEVEL - ABBREV.	DEFINITION	ACT LEVEL	N	CT MEAN	CT STD
1 - NONE	No philosophy core courses completed at NMSU.	ACT<22	184	63.11	3.56
		22-24	187	65.95	3.03
		25-28	218	67.77	2.87
2 - ONE COURSE	One philosophy core course that is not Logic has been been completed at NMSU.	ACT<22	29	63.41	3.50
		22-24	50	65.70	3.62
		25-28	55	67.40	2.80
3 - ONE = LOGIC	Logic is the only philosophy core course that has been completed at NMSU.	ACT<22	13	65.46	3.02
		22-24	25	64.52	4.34*
		25-28	35	68.26	2.66*

* F-max = 2.662 Significant at the 0.05 level for 9 variances with Mean(n)=88.

In the philosophy area students having one philosophy course were separated into two classifications based on whether the course was Logic or something else, specifically either Ethics or Introduction to Philosophy.

This distinction was made due to the traditional belief that logical reasoning is the primary basis for critical thinking.

Notice from Table 7 that a routine check on the equal CT variances assumption using Hartley's F-max test showed this assumption to be false ($p<0.05$). With unbalanced designs this can be a serious problem. Table 7 shows that both the largest standard deviation (4.34) and the smallest standard deviation (2.66) occurred for the Logic classification of philosophy, which was the classification with the fewest students. Specifically it was the variance estimate (STD=4.34) for those who had completed Logic with ACT composite scores of from 22 to 24 that led to a significant F-max. Where larger variances are associated with smaller sample sizes, as in this case, statistical tests on means will tend to be liberal (Glass & Hopkins, 1984). That is, the actual alpha error rate will be greater than that specified as the criterion for rejecting the null hypothesis. To deal with this potential problem the analysis will proceed as planned, but, should a significant philosophy effect emerge, additional pair-wise comparisons will be done on cell CT least squares means for means within levels of ACT excluding the middle level of ACT for the Logic classification (the high variance cell). This will result in seven planned comparisons between cell CT least squares means which should allow a meaningful conclusion in light of a potentially liberal F-test. Of course, if there is no significant effect even under the liberalized statistical test then further assessment will be unnecessary.

The results of the analysis of critical thinking scores for philosophy classifications controlling for ACT are summarized in Table 8. As can be seen from this table there was a significant Philosophy classification by ACT interaction, but no significant trend. Indeed, even though the test of interaction is likely to be a liberal one for the philosophy area, the p-value

(0.0175) seems small enough in comparison to the nominal alpha for this study (0.10) to be convincing. None the less additional assessment of this result was pursued.

Table 8
Philosophy Area
Analysis of Critical Thinking Scores
By Level of General Education Philosophy Requirements Met

SOURCE	DF	TYPE III SS	F VALUE	PR > F
Contrasts:				
Linear Trend	1	12.48906453	1.22	0.2689
Quadratic Trend	1	9.14800198	0.90	0.3440
Philosophy	2	14.75515460	0.72	0.4856
ACT	2	918.35975265	45.00	0.0001
Philosophy*ACT	4	122.98186816	3.01	0.0175
Error	787	8031.25110121		

LEAST SQUARES MEANS

PHILOSOPHY LEVEL	CT LSMEAN	STD ERROR LSMEAN	PROB > |T| HO: I/J	LSMEAN(I) = LSMEAN(J) 1	2	3
1 NONE	65.607	.132	1		.746	.269
2 ONE COURSE	65.505	.287	2	.746		.248
3 ONE + LOGIC	66.080	.406	3	.269	.248	

Table 9 shows all cell CT least squares means along with the p-values for all possible pair-wise comparisons of these cell means. The examination of this table should aid in determining the nature of interaction effect as well as provide the results for the seven planned pair-wise comparisons.

First consider the planned comparisons. The probabilities of greater T-statistic values for the seven planned comparisons have been underscored in Table 9. Two were significant, both showing higher critical thinking scores

for those who had completed a logic course, but only for students in the lowest ACT category. More specifically, for students with ACT composite scores less than 22, those who completed logic had a significantly higher CT mean than did both those who had completed one other-than-logic philosophy core course (p=0.055) and those who had not completed any core philosophy course (p=0.011).

Table 9
Philosophy By ACT Critical Thinking Least Squares Mean Comparisons

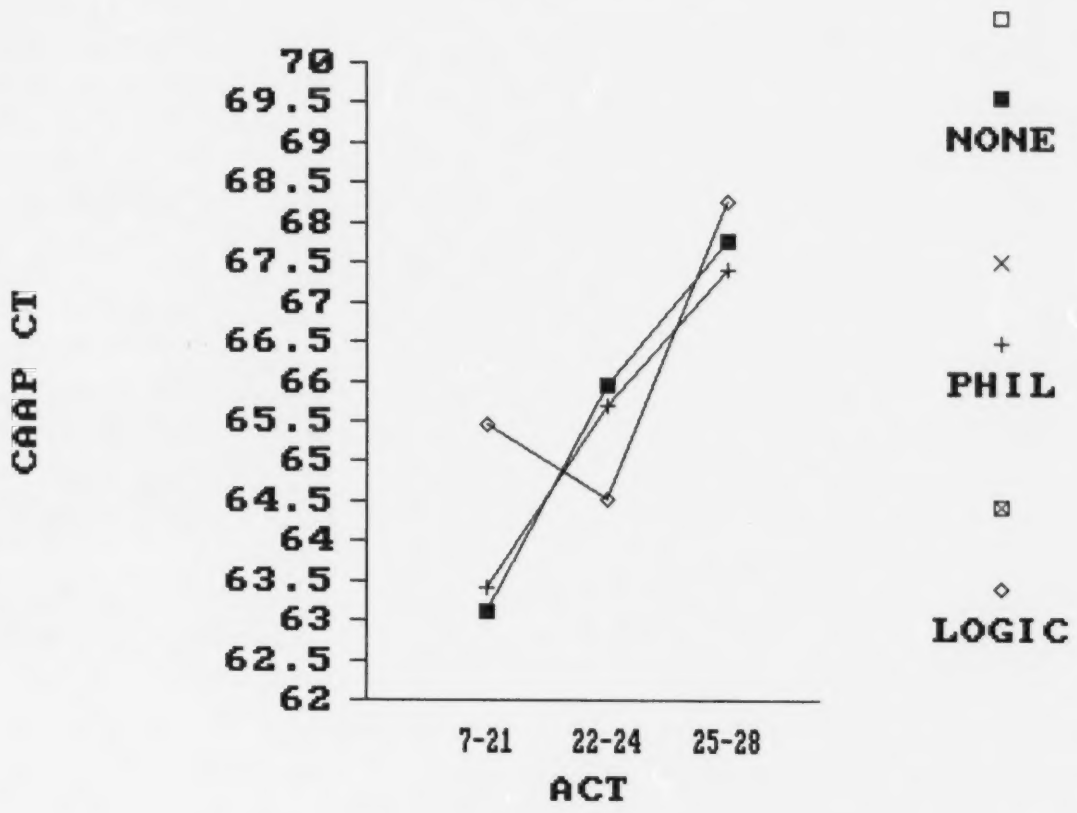
LSMEAN REF. NUM.	PHILOSOPHY LEVEL - ABBREV.	ACT LEVEL	CT LSMEAN	STD ERR LSMEAN
1	1 - NONE	ACT<22	63.109	0.236
2	1 - NONE	22-24	65.947	0.234
3	1 - NONE	25-28	67.766	0.216
4	2 - ONE COURSE	ACT<22	63.414	0.593
5	2 - ONE COURSE	22-24	65.700	0.452
6	2 - ONE COURSE	25-28	67.400	0.431
7	3 - ONE = LOGIC	ACT<22	65.462	0.886
8	3 - ONE = LOGIC	22-24	64.520	0.639
9	3 - ONE = LOGIC	25-28	68.257	0.540

PROB > |T| UNDER HO: LSMEAN(I) = LSMEAN(J)

I/J	1	2	3	4	5	6	7	8	9
1		.000	.000	.633	.000	.000	.011	.039	.000
2	.000		.000	.000	.628	.003	.597	.036	.000
3	.000	.000		.000	.000	.448	.012	.000	.399
4	.633	.000	.000		.002	.000	.055	.205	.000
5	.000	.628	.000	.002		.007	.811	.132	.000
6	.000	.003	.448	.000	.007		.050	.000	.215
7	.011	.597	.012	.055	.811	.050		.389	.007
8	.039	.036	.000	.205	.132	.000	.389		.000
9	.000	.000	.399	.000	.000	.215	.007	.000	

Figure 2 graphically displays the interaction effect observed, which has already been indicated by the pattern of significant differences between the cell CT least squares means, as discussed above and as shown in Table 9.

Figure 2
Critical Thinking Graphed by ACT Level for Each Philosophy Classification



Notice from Figure 2 that the interaction was disordinal. That is, having completed a logic course was associated with the highest level of CT scores for those with ACT scores below 22, but with the lowest level of CT scores for those with ACT scores from 22 through 24, while there was less than a one point difference between all three philosophy classifications for those with ACT scores from 25 through 28. Clearly the extent to which completion of the core logic course at NMSU was related to critical thinking performance depended upon the level of incoming ability.

Literature

The literature area gave rise to three hierarchical levels of meeting the general education core requirements. Table 10 defines these three literature

Table 10
Literature Area Classification Definitions
Cell Sizes, Critical Thinking Means and Standard Deviations

LITERATURE LEVEL - ABBREV.	DEFINITION	ACT LEVEL	N	CT MEAN	CT STD
1 - NONE	No literature NMSU core requirement course has been completed.	ACT<22	95	62.93	3.29
		22-24	103	65.39	3.32
		25-28	116	67.66	3.02
2 - ONE LIT	One literature course in the NMSU core requirement listing has been completed.	ACT<22	84	63.23	3.76*
		22-24	115	66.03	3.39
		25-28	144	67.77	2.82
3 - TWO OR MORE	Two or more literature courses in the NMSU core requirement listing have been completed.	ACT<22	50	63.96	3.71
		22-24	51	66.10	2.95
		25-28	53	68.08	2.39*

* F-max = 2.464 Significant at the 0.05 level for 9 variances with Mean(n)=90.

classifications as well as providing the relevant descriptive statistics for each level of ACT within literature classification. One should recognize that it is possible to meet NMSU's humanities requirements without completing a course in literature (see Appendix A).

As can be seen from Table 10 the homogeneity of variances assumption underlying any analysis of variance procedure was not tenable in this case as determined by Hartley's F-max test. With unbalanced designs this can be particularly problematical. However where the smaller variances tend to be associated with the smaller sample sizes, as tends to be the case here, the lack of homogeneity in variances results in a conservative test -- i.e. the actual alpha is less than the stated alpha. Secondly, the equal variances assumption was itself tested in a conservative fashion by using the alpha=0.05 criterion for F-max, which is less than the alpha=0.10 that was used in testing mean effects in this study. These two considerations suggest that proceeding to the planned unbalanced analysis of variance statistical procedures for the literature area in light of weak variance assumptions will simply lead to a conservative test of effects. With this in mind the analysis of literature classification effects on critical thinking proceeded as planned.

Table 11 reports the analysis of variance and trend analysis results. A significant linear trend was observed (p=0.0229). As seen from the least squares means in the lower portion of Table 11, the linear trend was such that higher critical thinking score means were associated with greater amounts of core literature area course work after controlling for three levels entering ability as measured ACT. Furthermore, one will notice from Table 11 that of

Table 11
Literature Area
Analysis of Critical Thinking Scores
By Level of General Education Literature Requirements Met

SOURCE	DF	TYPE III SS	F VALUE	PR > F
Contrasts:				
Linear Trend	1	53.17955974	5.19	0.0229
Quadratic Trend	1	0.02188624	0.00	0.9631
Literature	2	55.53978722	2.71	0.0671
ACT	2	2335.23070128	114.00	0.0001
Literature*ACT	4	15.24198373	0.37	0.8286
Error	802	8214.02769819		

LEAST SQUARES MEANS

LITERATURE LEVEL	CT LSMEAN	STD ERROR LSMEAN	PROB > |T| HO: LSMEAN(I) = LSMEAN(J) I/J	1	2	3
1 NONE	65.326	.181	1		.170	.023
2 ONE LIT	65.674	.177	2	.170		.237
3 TWO OR MORE	66.045	.258	3	.023	.237	

the three pair-wise comparisons between least squares means, those with two or more core literature courses completed significantly (p=0.023) out-perform those with no core literature courses completed.

Fine Arts

There were three classifications defined for the fine arts area of the NMSU general education core requirements. Table 12 defines these three classifications and provides the relevant descriptive statistics for each level of ACT within each fine arts classification. One should recognize that it is possible to meet NMSU's humanities requirements without completing a course in fine arts (see Appendix A).

Table 12
Fine Arts Area Classification Definitions
Cell Sizes, Critical Thinking Means and Standard Deviations

FINE ARTS LEVEL - ABBREV.	DEFINITION	ACT LEVEL	N	CT MEAN	CT STD
1 - NONE	No fine arts NMSU core requirement course has been completed.	ACT<22	95	62.98	3.29
		22-24	117	65.63	3.21
		25-28	164	67.94	2.74
2 - ONE COURSE	One fine arts course in the NMSU core requirement listing has been completed.	ACT<22	108	63.25	3.82
		22-24	118	65.95	3.26
		25-28	119	67.61	2.95
3 - TWO OR MORE	Two or more fine arts courses in the NMSU core requirement listing have been completed.	ACT<22	26	64.35	3.38
		22-24	34	65.82	3.70
		25-28	30	67.63	2.80
F-max = 1.934	Not significant at the 0.05 level for 9 variances with Mean(n)=90.				

Table 13 reports the analysis of variance and trend analysis results for the fine arts areas. There were no significant effects other than that expected for the controlling variable ACT. Thus there is insufficient evidence to suggest that critical thinking is related to completion of fine arts general education requirements at NMSU.

Table 13
Fine Arts Area
Analysis of Critical Thinking Scores
By Level of General Education Fine Arts Requirements Met

SOURCE	DF	TYPE III SS	F VALUE	PR > F
Contrasts:				
Linear Trend	1	12.41456600	1.21	0.2717
Quadratic Trend	1	2.40397478	0.23	0.6285
Fine Arts	2	12.41495945	0.60	0.5464
ACT	2	1497.24353589	72.95	0.0001
Fine Arts*ACT	4	44.60732156	1.09	0.3619
Error	802	8230.71906840		

LEAST SQUARES MEANS

FINE ARTS LEVEL	CT LSMEAN	STD ERROR LSMEAN	PROB > |T| HO: I/J	LSMEAN(I) = LSMEAN(J) 1	2	3
0 NONE	65.517	.169	1		.727	.272
1 ONE COURSE	65.601	.173	2	.727		.383
2 TWO OR MORE	65.934	.340	3	.272	.383	

Foreign Languages

Critical thinking scores were compared across three classifications of the degree to which general education foreign language courses were completed. Again it is noted (see appendix A) that a student can meet humanities requirements at NMSU without completing a foreign language course, unless a B.A. degree as opposed to a B.S. degree is the objective. The language level classifications are defined in Table 14 with cell sizes along with critical thinking means and standard deviations given for each ACT level of the classification.

Table 14
Foreign Language Area Classification Definitions
Cell Sizes, Critical Thinking Means and Standard Deviations

LANGUAGE LEVEL - ABBREV.	DEFINITION	ACT LEVEL	N	CT MEAN	CT STD
1 - NONE	No foreign language	ACT<22	157	63.26	3.52
	NMSU core requirement	22-24	186	65.82	3.27
	course has been completed.	25-28	209	67.71	2.86
2 - ONE LANG	One foreign language course	ACT<22	33	63.48	4.11*
	in the NMSU core requirement	22-24	48	65.19	3.13
	listing has been completed.	25-28	43	68.02	2.68*
3 - TWO OR MORE	Two or more language courses	ACT<22	39	63.08	3.35
	in the NMSU core requirement	22-24	35	66.51	3.49
	listing have been completed.	25-28	61	67.87	2.82

* F-max = 2.356 Significant at the 0.05 level for 9 variances with Mean(n)=90.

Notice from Table 14 that a routine check on the homogeneity of variances assumption, using Hartley's F-max test, showed this assumption to be false ($p<0.05$). Since the planned analysis utilizes an unbalanced analysis of variance design where robustness characteristics do not necessarily protect against such violations of assumptions, the consequences of proceeding must be considered. Notice from Table 14 that it was the large variance in the low ACT level of the ONE LANG classification (STD=4.11) that yielded the significant F-max, and that this was the cell containing the smallest number of students. Generally where the larger variances are associated with the smaller cell sizes a liberal test of means results--i.e. the actual risk of rejecting the null hypothesis when it is really true is greater than that implied by the specified alpha. Thus if a significant effect involving

language emerges in the analysis of variance procedures, the degree to which this presents sufficient evidence for a meaningful conclusion must be further assessed. This will be done by examining the relevant pair-wise comparisons among cell CT least squares means at the same ACT level, while excluding the large-variance-cell from comparisons within the ACT less than 22 set of three means, thereby focusing on five pair-wise comparisons. Of course, if no effect exceeds the nominal alpha=0.10 criterion used in this study, then the liberal nature of the test suggests a clear lack of significance with no additional assessments required.

The analysis of variance on critical thinking scores for language classifications controlling for ACT are summarized in Table 15. As can be

Table 15
Foreign Language Area
Analysis of Critical Thinking Scores
By Level of General Education Foreign Language Requirements Met

SOURCE	DF	TYPE III SS	F VALUE	PR > F
Contrasts:				
Linear Trend	1	5.20684239	0.51	0.4767
Quadratic Trend	1	1.90172204	0.19	0.6672
Languages	2	5.75149944	0.28	0.7559
ACT	2	1779.65266751	86.60	0.0001
Languages*ACT	4	37.66065881	0.92	0.4537
Error	802	8240.26868813		

LEAST SQUARES MEANS

LANGUAGE LEVEL	CT LSMEAN	STD ERROR LSMEAN	PROB > |T| HO: I/J	LSMEAN(I) = LSMEAN(J) 1	2	3
1 NONE	65.595	.137	1		.925	.477
2 ONE LANG	65.565	.291	2	.925		.531
3 TWO OR MORE	65.820	.284	3	.477	.531	

seen from this table there were no significant trends nor a language by ACT interaction. Thus given the liberal nature of this test, there is clearly insufficient evidence to suggest that the level of critical thinking performance is related to the number of core foreign language courses completed at NMSU.

History

Three levels of history were defined by the number of core history courses completed. History classifications are defined in Table 16 along with the critical thinking (CT) score means for each ACT level with in each history classification.

Table 16
History Area Classification Definitions
Cell Sizes, Critical Thinking Means and Standard Deviations

HISTORY LEVEL - ABBREV.	DEFINITION	ACT LEVEL	N	CT MEAN	CT STD
1 - NONE	No history NMSU core requirement courses have been completed.	ACT<22	102	63.37	3.48
		22-24	129	65.81	3.49
		25-28	152	67.71	2.89
2 - ONE HISTORY	One history course in the NMSU core requirement listing has been completed.	ACT<22	97	63.10	3.44
		22-24	119	65.83	3.03
		25-28	139	67.87	2.74*
3 - TWO OR MORE	Two or more history courses in the NMSU core requirement listing have been completed.	ACT<22	29	63.66	4.15*
		22-24	21	65.48	3.47
		25-28	22	67.73	3.01

* F-max = 2.296 Significant at the 0.05 level for 9 variances with Mean(n)=90.

Table 16 shows that the homogeneity of variances assumption is not tenable in this case as determined by Hartley's F-max test. Specifically the significant F-max test is brought about by the large variance (4.15) found for the low ACT level of the TWO OR MORE history courses classification. Since this large variance is associated with one of the smallest cell sizes (n=29) the consequences of violating the homogeneity of variances assumption in this case are that a liberal test of means is likely to result. Thus if a significant effect involving history is found by analysis of variance procedures the degree to which this presents sufficient evidence for a meaningful conclusion must be further assessed. As in the previous section, this will be done by examining the relevant pair-wise comparisons among cell CT least squares means at the same ACT level, while excluding the violating cell from such comparisons. If no effect exceeds the nominal alpha=0.10 criterion used in this study, then the liberal nature of the test indicates a clear lack of significance with no additional assessments required.

Table 17 summarizes the analysis of variance on critical thinking scores for history classifications controlling for ACT. As can be seen from this table there were no significant effects involving history. Thus given the liberal nature of this test, there is clearly insufficient evidence to suggest that the level of critical thinking performance is related to the number of core courses in history completed at NMSU.

Table 17
History Area
Analysis of Critical Thinking Scores
By Level of General Education History Requirements Met

SOURCE	DF	TYPE III SS	F VALUE	PR > F
Contrasts:				
Linear Trend	1	0.00971736	0.00	0.9755
Quadratic Trend	1	0.08190130	0.01	0.9288
History	2	0.16753926	0.01	0.9919
ACT	2	1530.45046172	74.59	0.0001
History*ACT	4	12.11849657	0.30	0.8811
Error	801	8218.07142699		

LEAST SQUARES MEANS

HISTORY LEVEL	CT LSMEAN	STD ERROR LSMEAN	PROB > |T| HO: LSMEAN(I) = LSMEAN(J) I/J	1	2	3
1 NONE	65.632	.166	1		.898	.976
2 ONE HISTORY	65.602	.172	2	.898		.966
3 TWO OR MORE	65.620	.381	3	.976	.966	

Social Sciences

Four levels of social science were defined by the number of core listed social science courses other than history that had been completed. Table 18 specifies the definitions for each of these social science classifications in addition to providing the critical thinking (CT) score means and standard deviations for each ACT level within each of these classification. It should be pointed out that the listing of core courses used in these classifications

(see Appendix A) is quite diverse in comparison to the other academic areas. This heterogeneity of content and related instructional methods undoubtedly weakens the potential to observe a significant relationship between classifications and critical thinking for this loosely defined area.

Table 18
Social Sciences Area Classification Definitions
Cell Sizes, Critical Thinking Means and Standard Deviations

SOCIAL SCIENCES LEVEL - ABBREV.	DEFINITION	ACT LEVEL	N	CT MEAN	CT STD
1 - NONE	No social sciences	ACT<22	27	63.22	3.76
	NMSU core requirement	22-24	21	65.86	3.31
	courses have been completed.	25-28	29	67.52	2.81
2 - ONE COURSE	One social sciences course	ACT<22	71	63.52	3.70
	in the NMSU core requirement	22-24	84	65.99	3.55
	listing has been completed.	25-28	114	67.83	2.96
3 - TWO COURSES	Two social sciences courses	ACT<22	94	62.78	3.48
	in the NMSU core requirement	22-24	112	65.67	3.29
	listing have been completed.	25-28	119	68.04	2.57
4 - THREE-MORE	Three or more courses	ACT<22	37	64.03	3.35
	in the NMSU core requirement	22-24	52	65.73	2.87
	listing have been completed.	25-28	51	67.22	3.06
F-max = 2.131	Not significant at the 0.05 level for 9 variances with Mean(n)=68.				

Table 19 summarizes the analysis of variance on critical thinking scores for social sciences core course work controlling for ACT. As can be seen from this table there were no significant effects involving social sciences.

Table 19
Social Science Area
Analysis of Critical Thinking Scores
By Level of General Education Social Science Requirements Met

SOURCE	DF	TYPE III SS	F VALUE	PR > F
Contrasts:				
Linear Trend	1	0.04419411	0.00	0.9477
Quadratic Trend	1	0.27438828	0.03	0.8702
Cubic Trend	1	11.52938619	1.12	0.2896
Social Sciences	3	12.41730838	0.40	0.7508
ACT	2	1819.13234321	88.60	0.0001
Social Sciences*ACT	6	71.05310518	1.15	0.3294
Error	799	8202.72561848		

LEAST SQUARES MEANS

SOCIAL SCI. LEVEL	CT LSMEAN	STD ERROR LSMEAN	PROB > |T| HO: I/J	LSMEAN(I) - LSMEAN-(J) 1	2	3	4
1 NONE	65.532	.369	1		.553	.930	.785
2 ONE COURSE	65.781	.199	2	.553		.287	.717
3 TWO COURSES	65.496	.179	3	.930	.287		.621
4 THREE-MORE	65.658	.274	4	.785	.717	.621	

Therefore there is insufficient evidence to suggest that the level of critical thinking performance is related to the number of core courses completed from the non-history social science requirements listing at NMSU.

CONCLUSIONS AND DISCUSSION

This study has explored the relationship between CAAP critical thinking scores and the extent to which students have met core general education course requirements at NMSU. The design employed for this purpose controlled for three levels of entering ability as measured by ACT composite scores (7-21, 22-24 & 25-28). Within the nine academic areas of the general education core, patterns of critical thinking (CT) least squares means were investigated using a two-way unbalanced analysis of variance design and orthogonal polynomial contrasts. There were no significant (alpha=0.10) effects on critical thinking in five of the nine areas: mathematics, fine arts, foreign languages, history and social sciences. Significant trends in critical thinking scores were found for communications, science, literature and, in philosophy, a significant philosophy by ACT interaction effect was found.

In communications significant linear and cubic trends in CT least squares means emerged in a unique fashion, both showing that CT scores actually decreased as the degree to which students met communications core requirements increased. However, since the communications variable classifications were defined by courses taken at NMSU, and since a large proportion of students enter NMSU with English Composition I credit from an advanced high school program offered to high achieving students, these trends appear to simply indicate that these academically advanced students have higher critical thinking skills than others. Comparisons excluding classifications contaminated by this selection bias resulted in no significant differences in critical thinking scores. Therefore with respect to communications requirements completed at NMSU, there was actually insufficient evidence to

conclude that a relationship to critical thinking scores existed.

In science a significant linear trend was found. This trend was such that CT least squares means tended to be higher with greater levels of science core requirements met. Indeed, the greatest CT least squares mean occurred for those students who had met the core requirement in the most typical fashion, two 100-level science courses. The CT least squares mean difference between those with no science and those with the minimum requirement met was about 0.6 of a CT scale score point. Generally science courses necessitate visualizing the relationship between constructs and problem solving activities in laboratory work with objectives that are both hierarchical and integrative. Thus the speculation that the nature of science content is closely related to critical thinking would find support in these results.

The literature area also produced a significant linear trend. The nature of this trend was that CT least squares means were higher for higher levels of the literature variable (NONE, ONE COURSE, TWO OR MORE). The difference between adjacent levels of literature was about 0.36 of a critical thinking scale score point, with the difference between lowest and highest levels being 0.72. Literature involves the analysis of literary works, synthesis of ideas and recognizing relationships. Thus, as with science, these results support the contention that the nature of literature content is associated with critical thinking skills.

The philosophy area was the only area in which a significant interaction effect was observed. The interaction was such that for those with ACT scores of 7-21, having completed a logic course was associated with significantly higher CT least squares means. For higher ACT levels, CT means for the "Logic" classification were either lower or about the same as those for the "No Philosophy" and "One Philosophy" classifications. This might suggest that

those with lower entering ability could benefit more from a course in logic than those with higher entering abilities with respect to the development of critical thinking skills. Logic involves manipulation of propositions in sound and valid fashion to come to conclusions, as well as the recognition of assumptions and fallacies in existing arguments. It is interesting to note that logic is the course most frequently and traditionally referred to in higher education in connection with critical thinking skills. The results presented for the "Logic" classification support this connection, at least for those with lower entering ability.

In general these results suggest that critical thinking skills will tend to be higher for students who have met or exceeded the NMSU core content area requirements in science and literature. In philosophy they will tend to be higher than otherwise expected for those who have ACT scores below 22 who also take Logic as one of the courses needed to meet their humanities requirements.

In reviewing these results it must be recognized that there were several important factors that could not be controlled in this investigation. Consequently, there are several possible explanations for the relationships observed.

The most direct explanation has already been mentioned. It is that certain content areas are more conducive to the development of critical thinking skills than other content areas. On the other hand, teaching methods are clearly important when considering the development of critical thinking skills. There were no attempts to control for teaching methods or the professors who actually instructed the core courses examined in this study. Thus an alternative explanation for the results observed might be that it is the teaching methods used in the science, literature and philosophy areas that

are associated with higher critical thinking in students rather than the nature of the content. Of course, there are usually several professors who teach the core courses at NMSU. Consequently if teaching methods accounts for variance in students' CT scores, then a higher concentration of faculty using methods that facilitate critical thinking are apparently in the areas of science, literature and philosophy. Recognize that this explanation is not independent of the nature of content explanation, since the nature of content to some extent, either directly or indirectly, dictates the teaching methods that are most effective for that area of study. Thus the two possible explanations in combination with one another probably offers a more likely explanation than each possibility does separately. Qualitative follow up studies focusing on course processes might provide some clarification in this vein.

It should be noted that if the nature of content, or teaching methods, or a combination of both can be regarded as the active ingredient underlying the relationships to critical thinking observed, then those academic areas that are most heterogeneous in these respects would have the greatest difficulty in showing a relationship to CT on the basis of classification definitions used in this investigation. The area at the greatest relative disadvantage in this regard is social sciences (excluding history), since classifications for this area include content and instruction in a somewhat diverse set of courses: psychology, economics, sociology, geography, anthropology and political science (see Appendix A).

Another set of possible explanations is related to the lack of control over courses taken outside of the nine focus areas, the sequence in which students completed courses, or the courses students were currently taking at the time of their CT examination. First, when doing the analysis in each area

classification, there was no control over the extent to which students met requirements in the other eight areas. Suppose for example that students who are classified at higher levels of meeting literature requirements tend to be students who have already met all or most of the requirements in other areas, say in mathematics and science. In such a case the relationship between CT and literature may be due to the other areas. Regarding the way students sequence their required courses, some sequences may be linked to higher critical thinking on the part of students. Others may actually be more potent in developing critical thinking skills. Some sequences may be related to the students major, with some majors requiring greater critical thinking skills than others. Others may simply be a matter of which course was available that fit the student's schedule. Finally, there is the possibility that when students take the CT test the courses they are currently in, which on the average are at a higher level, are more related to critical thinking than the those that have already been completed. If nothing else, current courses are likely to be a more potent influence on current thinking by virtue of more recent involvement. The relationship of current course work to critical thinking would make an interesting extension to this study.

In reviewing these results it must be noted that the relationships recognized are not necessarily cause and effect relationships. It is possible that there is something about the study of science, literature and/or philosophy that encourages the development of critical thinking. But, it is also possible that those who are already quite proficient in critical thinking are the majority of those who chose to meet science, literature and/or philosophy requirements earlier than others and/or in more rigorous ways than others to thereby get placed in higher level science, literature and/or philosophy classifications. Notice that if this latter situation were the

case, and since the same students are used in each of the nine area analyses, it would be more difficult for other areas to be significantly related to student critical thinking skills since science, literature and philosophy may have soaked up those students with the greatest critical thinking ability.

For the assessment purposes motivating this investigation, the question as to whether the chicken or the egg came first is not really important. If it is the case that the content/instruction aspects of science, literature and philosophy are behind the significant patterns of critical thinking score means observed, then this suggests course areas and in some cases specific courses that should be given early consideration in the advising process, particularly for students who have weak critical thinking skills. It also suggests areas in the curriculum that appear to be important in reaching critical thinking objectives in the university liberal arts and sciences core program. On the other hand if it is the case that students who already have good critical thinking skills tend to select science, literature and philosophy course work more frequently, then this again suggests areas or specific courses that should be considered in advising students. Students will tend to regress to the mean level of group performance. Furthermore, simply associating with classmates who demonstrate critical thinking skills is beneficial. Moreover, classmates often help one another in study groups, projects, etc. Similarly, with an eye on curriculum, the areas and courses that attract students with good critical thinking skills are important to recognize in any curriculum review process. Thus for the purposes of advising or curriculum review, this investigation has identified areas that have the best chances of improving critical thinking skills in NMSU students.

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APPENDIX A

Northeast Missouri State University
Liberal Arts and Sciences Core

Liberal Arts and Sciences Core

Communications 9

LL 100 English Comp. I (3 hours)
LL 170 Speech Communication (3 hours)
LL 314 English Comp. II (3 hours)

Mathematics and Science 14-15

Minimum of 3 hours in mathematics and minimum of 8 hours in science required. ***The additional 3-4 hours can be taken from either mathematics or science to total the required 14-15 hours.***

Minimum math requirement may be fulfilled by completing any of the following:

MATH 156 College Algebra (3 hours) **and** MATH 157 Plane Trigonometry (2 hours)
or MATH 186 Elementary Functions (3 hours)
STAT 190 Statistics (3 hours)
MATH 192 Essentials of Calculus (4 hours)
MATH 198 Analytic Geometry and Calculus I (5 hours)
Any Higher Level Mathematics or Statistics Course

Minimum science requirement may be fulfilled by completing 1 course from 2 of the following areas:

AREA I
BIOL 100 Biology (4 hours)
or BIOL 107 Intro. Biology I (4 hours), BIOL 108 Intro. Biology II (4 hours)
or BIOL 103 General Botany (4 hours)
or BIOL 106 General Zoology (4 hours)

AREA II
CHEM 100 Chemistry (4 hours)
or CHEM 120 General Chemistry I (4 hours), CHEM 121 General Chemistry II (4 hours)
or CHEM 110 Basic Chemistry I (3 hours) **and** CHEM 111 Basic Chemistry II (3 hours)*

* Must complete sequence

AREA III
PHYS 100 Physics (4 hours)
or PHYS 285 General Physics I (5 hours), PHYS 286 General Physics II (5 hours)
or PHYS 185 College Physics I (5 hours), PHYS 186 College Physics II (3 hours)

Health, P.E. and Recreation/ Military Science 2

HLTH 194 Health and Wellness (2 hours)
or MS 100 (1 hour) **and** MS 101 (1 hour)

Humanities 15

(Select 5 courses from the 4 areas listed below, with no more than 2 courses from each area)

AREA I
SS 186 Philosophy (3 hours)
SS 255 Logic (3 hours)
SS 256 Eastern Religious Thought (3 hours)
SS 257 Ethics (3 hours)

AREA II
LL 200 World Literature I (3 hours)
LL 201 World Literature II (3 hours)
LL 300 English Literature I (3 hours)
LL 301 English Literature II (3 hours)
LL 302 American Literature I (3 hours)
LL 303 American Literature II (3 hours)
LL 315 Shakespeare (3 hours)
LL 321 French Literature I (3 hours)
LL 322 French Literature II (3 hours)
LL 329 Readings in Hellenistic Greek Literature (3 hours)
LL 332 Introduction to German Literature I (3 hours)
LL 333 Introduction to German Literature II (3 hours)
LL 363 Spanish Literature Survey (3 hours)
LL 423 Modern French Literature (3 hours)
LL 466 Survey of Latin American Literature I (3 hours)
LL 467 Survey of Latin American Literature II (3 hours)
LL 468 Spanish Literature of the Golden Age (3 hours)

AREA III
FA 125 Art Survey I (3 hours)
FA 126 Art Survey II (3 hours)
FA 200 Basic Approach to the Arts (3 hours) **or** FA 300 Arts and Man (3 hours)
FA 203 Art Appreciation — Aesthetics (3 hours)
FA 204 Music Appreciation (3 hours)
FA 225 Ancient Art History (3 hours)
FA 226 Renaissance Art History (3 hours)
FA 240 Music Literature (3 hours)
FA 325 19th Century Art (3 hours)
FA 326 Contemporary Art (3 hours)
FA 340 History of Music I (3 hours)
FA 341 History of Music II (3 hours)
LL 275 Theatre Appreciation (3 hours)

(over)

AREA IV

LL 102 Intermediate English I & II (For Foreign Language) (6 hours)
LL 103 Advanced English I & II (For Foreign Language) (6 hours)
LL 120 Elementary French I (3 hours)
LL 121 Elementary French II (3 hours)
LL 220 Intermediate French I (3 hours)
LL 221 Intermediate French II (3 hours)
LL 130 Elementary German I (3 hours)
LL 131 Elementary German II (3 hours)
LL 230 Intermediate German I (3 hours)
LL 231 Intermediate German II (3 hours)
LL 119 Elementary Japanese I (3 hours)
LL 219 Elementary Japanese II (3 hours)
LL 419 Japanese Language & Culture III (3 hours)
LL 150 Elementary Latin I (3 hours)
LL 151 Elementary Latin II (3 hours)
LL 290 Intermediate Latin I (3 hours)
LL 291 Intermediate Latin II (3 hours)
LL 115 Elementary Russian I (3 hours)
LL 116 Elementary Russian II (3 hours)
LL 215 Intermediate Russian I (3 hours)
LL 216 Intermediate Russian II (3 hours)
LL 160 Elementary Spanish I (3 hours)
LL 161 Elementary Spanish II (3 hours)
LL 163 Intensive Elementary Spanish (6 hours)
LL 260 Intermediate Spanish I (3 hours)
LL 261 Intermediate Spanish II (3 hours)
LL 110 Koine Greek I (3 hours)
LL 111 Koine Greek II (3 hours)
LL 211 New Testament Greek (3 hours)
LL 329 Hellenistic Greek Literature (3 hours)
LL 112 Elementary Chinese I (3 hours)
LL 113 Elementary Chinese II (3 hours)
LL 108 Elementary Hebrew I (3 hours)
LL 109 Elementary Hebrew II (3 hours)

Social Science 9

(Select one of the following options with approval of advisor)

OPTION I

Elect one sequence of two courses from the following:

SS 104 American Experience I (3 hours)
SS 105 American Experience II (3 hours)
SS 120 World Civilizations I (3 hours)
SS 121 World Civilizations II (3 hours)

Elect one course from the following:

SS 111 Introduction to Geography (3 hours)
SS 130 Introduction to Economics (3 hours)
SS 166 General Psychology (3 hours)
SS 171 Introduction to Political Science (3 hours)
SS 190 Introduction to Sociology (3 hours)
SS 191 Introduction to Anthropology (3 hours)
SS 200 Principles of Macroeconomics (3 hours)
SS 201 Principles of Microeconomics (3 hours)

OPTION II

Elect one course from the following:

SS 104 American Experience I (3 hours)
SS 105 American Experience II (3 hours)

SS 120 World Civilizations I (3 hours)
SS 121 World Civilizations II (3 hours)

Elect two courses from the following:

SS 111 Introduction to Geography (3 hours)
SS 166 General Psychology (3 hours)
SS 171 Introduction to Political Science (3 hours)
SS 190 Introduction to Sociology (3 hours)
SS 191 Introduction to Anthropology (3 hours)
SS 200 Principles of Microeconomics (3 hours)
or SS 201 Principles of Macroeconomics (3 hours)
or SS 130 Introduction to Economics (3 hours)

Liberal arts and sciences	
Core:	49-50 sem. hours
Discipline directed program requirements:	10-11 sem. hours
Additional B.S. degree required science-based courses OR B.A. degree required foreign language courses:	12 sem. hours
Total liberal arts and sciences component	**72 semester hours**
Major component	**minimum of 30 semester hours**
	Electives
Minimum program requirement	124 semester hours

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